Ontario Ministry of Housing
Technical Support Services Branch

REPORT

concerning

RELOCATION AND OPERATION OF MAKE-UP AIR VENTILATION SYSTEMS IN WALK-UP RESIDENTIAL BUILDINGS

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1.0 EXECUTIVE SUMMARY

This engineering study evaluates make-up air systems, installed in attics, in Ontario Housing Corporation's low rise residential buildings. The terms of reference are to identify existing problems and to provide alternatives and recommendations, concerning these problems.

For many buildings inspected, the systems are not operating properly. A major problem is accessibility, both for day to day operation and for maintenance.

Recommendations are provided to upgrade the systems. This includes the retrofit of outdoor air dampers, new staging controls and improved insulation. Standardized operating schedules are recommended to reduce energy costs.

Noise and vibration from the systems have been investigated. These problems are not common; where necessary field personnel have made successful modifications. Recommendations are provided to install spring isolators for future occurrences.

Alternatives have been investigated for relocation of the systems. These include both modifications in the attic and relocation elsewhere in the building. Relocation as opposed to modification, is recommended since the overall costs are comparable and accessibility is improved.

For systems with remaining useful lives of less than ten years, relocation should be in conjunction with replacement of the system. This will have higher first costs but the life cycle costs will be approximately equal. Where possible, replacement of the system should include a conversion to natural gas. This will lower annual operating costs and will significantly reduce overall life cycle costs.

2.0 INTRODUCTION

2.1 General Information

The study is based on investigations at ten buildings. These were selected by the Ministry as being representative of typical OHC walk-up facilities. The buildings are one and two storey structures having between 12 and 75 suites. A summary listing of the buildings inspected is provided in Appendix 1, page 13.

2.2 Description of the Ventilation Systems

Electrically heated make-up air systems are installed in all facilities. The systems provide outside air at rates from 500 L/s (1060 cfm) to 1000 L/s (2120 cfm). Buildings with more than 30 suites normally have more than one system. The systems are controlled by thermostats to maintain supply air temperature; for the buildings inspected this was between 10 ^{o}C (50 ^{o}F) and 24 ^{o}C (75 ^{o}F). The systems have between three and six heater stages. Limit thermostats are installed to prevent operation below 8 ^{o}C (20 ^{o}F).

Most buildings have individual suite exhaust fans; otherwise, there are grouped or central exhaust systems for kitchens and washrooms. In addition, most buildings have small individual exhaust fans for the garbage room, the laundry room and the common room.

Timers have been installed to schedule the operation of the make-up air systems for all the buildings visited. In one case, the timer was not operating; the trippers had been removed.

The current Ministry of Housing design requirements for make-up air systems are summarized in Appendix 2, page 14.

3.0 DISCUSSION

3.1 Findings and Problems

This section provides descriptions of problems noted from inspections and discussions with maintenance supervisors. The applicable problems vary site by site.

1. Access to the Attic

   Access to the attic is poor; using a step ladder through a covered hatch. All maintenance supervisors indicated this problem. In some cases, the opening is blocked by ducting in the attic, above the corridor. Access may be improved by installing a folding ladder stairway. This is estimated to cost $1790. (Ladder assembly $290; installation $1500).

2. Accessibility of the Systems

   Inside the attic, accessibility to the equipment is obstructed by roof truss members and loose roof insulation; lighting is inadequate; often, there is no work platform installed over the ceiling joists. Modifications are discussed in Section 3.2.1.

3. Outdoor Air Dampers

   Many systems installed in attics do not include motorized outside air dampers. Cold air can feed, by gravity, when the systems are shut off. In some cases systems are run continuously to prevent drafts. Retrofit of motorized dampers are estimated at $700 (dampers $500, installation $200).

4. Maintenance

   Many existing systems are operating with defective heater coils. While this can be considered a routine maintenance problem, it may also indicate other problems. The heaters could be operating with inadequate air flow, caused by plugged air filters or staging controls which are improperly calibrated. In extreme cases, it could be due to gravity fed cold air activating the thermostat sensor.

5. Discharge Air Controls

Thermostat overrides have been installed in most buildings. When the corridor temperature is satisfied the heater elements are off. Cold air is discharged, causing drafts and discomfort. The override controls have been disconnected at many sites, including all buildings in Grey County and Owen Sound.

Operation may be improved by installing a new discharge control with reset from corridor temperature (Honeywell W7100). This will prevent overheating while maintaining the supply air temperature within an acceptable range. The estimated cost is $1835 (control/sensors $1535, installation $300). Product literature – Appendix 5.

6. Outside Air Roof Intake Hoods

For some systems, the outside air is taken through a roof mounted weather hood. These systems can not be operated in summer because of the intake of hot air from the roof deck. Relocation of the system to draw outside air through the end wall will eliminate this problem. The estimated cost is $1200 per system.

7. Insulation

In many cases, the supply air ducting is not insulated to Ministry standards (25 mm foil backed and taped). Costs are can not be estimated; duct lengths and size varies site by site. The unit cost is approximately $2.90 per sq. foot.

8. System Air Volumes

In some cases, the systems are not sized to Ministry standards. This often reflects differences between the existing and previous design standards. Often, improvements can be made by pulley ratio adjustments of the blower and motor. Implementation will require air volume measurements and pulley changes. Estimated cost $150 per system.

9. Operating Schedules

On average, the systems inspected operate 12.5 hours per day. The Ministry recommends operation of 6 hours per day. Operating costs can be reduced by applying standardized schedules. These changes can be implemented at no cost.

10. Corridor Heat

In one building inspected, there are no baseboard heaters in the corridors. The make-up air system is operated continuously to provide basic heating. Operating costs can be reduced by installing baseboard heaters. Cost will vary site by site; based on a two storey building requiring five heaters, the cost is estimated to be $1100.

11. Noise and Vibration

Vibration and noise may be transmitted if the make-up air unit is not isolated from the building structure. Systems in attics are installed directly on the ceiling joists, often over a concrete pad. Occasionally, the systems are hung using steel straps and rubber isolators.

Of the buildings inspected, none presently exhibited a problem with noise and vibration. No problems were reported for any building in either Northumberland County or South Simcoe and Barrie. One building in Peel Region and one in Owen Sound had previously been successfully modified using steel straps and rubber isolators. The estimated cost for vibration isolators is $350 per system (materials $150; labour $200). Product Literature – Appendix 5.

3.2 Alternatives for Relocation of the Systems

3.2.1 Modify the Existing System in the Attic

The installation in the attic can be improved by:

1. Installing a folding stair system.
2. Installing a plywood walkway over the ceiling joists.
3. Elevating the components and suspending these from the roof truss system using spring isolators.

3.2.2 Relocation Outside the Attic

Systems may be relocated outside the attic. The existing supply ducting would be re-used. The connections would be routed to the attic through the stairwell, garbage or mechanical rooms depending on the layout of individual buildings.

Alternative locations for relocation of the systems have been considered; a discussion of these follows.

Mechanical/Storage Rooms

Some buildings have separate mechanical/storage rooms. These typically house domestic hot water systems and possibly electrical distribution panels.

The advantages of this location are ease of access and isolation from the resident population. The disadvantage is that rooms are often located on the first floor interior, which complicates re-routing of the ducting.

These areas are recommended as the best alternative for system relocation.

Outside Storage Room

Most buildings provide an outside storage room. This is used for the yard tractor and other service tools. The room is typically located at one end of the building. A make-up air system would be hung from the ceilings at the rear of the room. Make-up air would be ducted directly from outside through a new grill connection. For the buildings inspected there was adequate space and this procedure would not significantly interfere with the storage of yard equipment and tools.

The room is presently used for the storage of pesticides and gasoline. To prevent any possibility of air contamination due to leakage through the fan housing, it would be necessary to install an exterior metal shed adjacent to the existing room. This would be used for all chemicals and gasoline.

The advantages of this location are ease of access and isolation from the resident population. The disadvantages are: the loss of space and congestion for storage; also this location is at ground level and would require relatively long and complicated re-ducting.

Outside storage rooms are recommended if space is not available in inside mechanical/storage rooms.

Garbage Rooms

This is the area most commonly used in existing relocations. The advantages are location and available space; garbage room facilities are normally located on upper floor corners, allowing simple re-connection to the existing ducting. The disadvantage is odours which may be distributed throughout the building.

Garbage rooms are not recommended due to odour transfer unless suitable space is absolutely not available in the mechanical rooms or the outside storage room.

Laundry Rooms

All buildings have laundry room facilities. The advantages would be ease of access. The

disadvantages are: increased congestion in a high traffic service area; undesirable accessibility by the resident population; first floor locations which complicate re-ducting.

Laundry rooms are not generally recommended.

Common Rooms

All buildings have common room facilities. Use of this area would required partitioning of the room to provide separate mechanical space. The advantages are ease of access. The disadvantages are loss of space to the residents; first floor locations which complicate re-ducting in two storey buildings.

Common rooms are not recommended unless the building is single storey and other space is not available.

Storage Closets

Many buildings have storage closets; where necessary these could often be constructed at the end of corridors. The advantages would be: improved access and ease of re-ducting. The disadvantages are congested installation space for maintenance. Storage closets are not recommended.

3.3 Conversion to Natural Gas

Natural gas is available at many sites. In some cases, the Ministry is implementing programs to convert DHW systems. For these buildings, conversion of the make-up air systems will reduce operating costs.

In most cases, the conversion to gas will be practical only when done in conjunction with a conversion of the DHW system. The make-up air supply systems only operate a few hours per day and the annual energy consumption is relatively low; by itself this would not justify the installation of a natural gas service.

4.0 Cost Analysis

4.1 Life Cycle Costs

Alternatives have been evaluated using twenty year life cycle costs. Twenty years is chosen since the present value of expenditures beyond this is small (approximately $.10 per $1.00 expenditure); these costs will have minimal impact on the analysis. This analysis considers first cost, operating and maintenance costs. Energy cost savings from modifications and schedule changes are included in the analysis. For comparison, present value analysis is used to convert all costs to 1990 dollars. The assumptions incorporated into the analysis are provided in Appendix 4.

	First Costs	Life Cycle Costs
1. Modify the existing system in the attic	$ 9,075	$56,576
2. Relocate the existing system	$12,075	$59,576
3. Replace and relocate the existing system	$22,350	$58,129
4. Repl./relocate and convert to gas	$25,350	$38,453

These figures indicate that among the alternatives keeping electricity as energy source (Alternatives 1, 2 and 3), the lowest cost alternative is to modify the existing system in the attic; the life cycle cost to relocate or replace the systems are approximately equal. If the existing system is replaced (Alt. 3 and 4) the first costs are significantly higher.

If replacement of the system is included with a conversion to natural gas the life cycle costs are significantly reduced.

Detailed estimates of first costs are provided in Appendix 3, pages 15 to 18. Details of the cost analysis, including annual disbursements are provided in Appendix 4, Tables A4.1 to A4.4, pages 20 to 23.

4.2 Sensitivity Analysis

The life cycle costs will be most sensitive to the discount rate (modeled at 12%) selected and to the timing of future system replacements (modeled at 10 years). The discount rate is tied to interest rates and as such, is impossible to forecast over a long term period.

Other costs, for maintenance and operations are also sensitive to the assumptions but these will tend to impact equally on all the alternatives analyzed.

For the alternatives considered, the basic decision is between replacing (Option 3) or relocating the existing system (Option 2). The life cycle cost to replace the system is estimated to be $58,129.

To test the sensitivity of the analysis, the option to relocate the existing system has been evaluated considering alternatives for the timing of future system replacements. The results are as follows:

Discount Rate	5 year Repl.	10 year Repl.	15 year Repl.
12%	$64,039	$59,576	$56 343

Considering that the life cycle cost of replacing the system immediately is estimated to be $58,129, the sensitivity analysis shows that, for a discount rate of 12%, relocating existing systems will provide reduced life cycle costs if these systems have useful operating lives greater than 10 years.

5.0 Conclusions

1. For existing make-up air systems, installed in attics the main problems are accessibility and maintenance. The problems with accessibility have contributed to the those of maintenance.

2. Often, the existing systems are in poor condition. Some are not correctly sized according to existing Ministry standards.

3. The existing attic installations can be improved by modifications in the attic; however, the problems will only be eliminated by relocation of the systems to other areas. The best location for relocation are mechanical rooms or the outside storage room. Where necessary garbage rooms may be used; however this is not generally recommended due to the possible distribution of odours..

4. The first costs to replace the system are approximately double the cost to repair and relocate the exjsting system; however, the twenty year life cycle costs are approximately equal.

5. Significant cost reductions can be achieved if replacement of the systems is done in conjunction with a conversion to natural gas.

6.0 Recommendations

1. Modify the existing systems to conform to all necessary Ministry standards. This includes installing motorized outdoor air dampers, improved duct insulation, vibration isolators and flexible duct connections to the air handling systems.

2. Install new discharge air controls, to replace make-up air thermostat overrides.

3. Relocate systems from the attic to other areas in the building; specifically mechanical rooms or outside storage rooms.

4. Where the existing system is in poor condition and is judged to have less than 10 years remaining useful life, it is recommended to replace the system in conjunction with relocation.

5. Where systems are replaced and depending upon the availability convert the energy source to natural gas. Implement the conversion for both the DHW and make-up air systems.

APPENDIX 1

Summary of the Buildings Inspected
Ontario Ministry of Housing

Location	Address	Bldg. Code
Alliston	109 Wellington St.	401-0130
Bolton	60 Jane St.	405-0050
Caledon	1640 Maple St.	
Durham	230 Queen St.	
Brighton	12A Mead St.	407-0030
Brighton	12 Mead St.	407-0010
Brighton	2 Francis St.	407-0050
Colborne	6 Percy St.	407-1070
Colborne	8 King St.	407-0190
Cobourg	330 King St.	407-1050

APPENDIX 2

Existing Standards - Make-up Air Systems
Ontario Housing Corporation

The general system design requirements for make-up air systems are currently detailed in Ministry of Housing Technical Guide, Section C.15.19. Previously, the requirements were the Technical Specification Requirements for the design of existing OHC buildings. In one and two storey structures the current standard requires supply air equal to 60% of the total exhaust rate where central exhaust systems are used and 50% where individual suite exhausts are used. The standard for individual suite exhaust is: kitchens - 30 L/s; bathrooms 20 L/s. .

Duct work passing through the attic, is to be insulated with 25 mm glass fibre insulation having foil vapour barrier (Section C15.19.7.28).

Flexible canvas connections (Section C15.19.7.24) are required to connect make-up units to duct work. Vibrator isolators are required for fan housings (Section C15.19.20).

APPENDIX 3

SECTION A3.1

Modify the Existing System in the Attic

General Description

This section details relocation of the existing system within the attic. This will require:

1. Installing a folding stair system to the attic.
2. Installing a plywood walkway above the insulation and along the attic centre corridor.
3. Elevation of the air handling components and suspension from the roof truss system using spring isolators.
4. Installation of outside air dampers, new discharge air controls and upgrading of duct insulation

Cost Estimate

Capital Cost equipment, controls	
Control Package - Honeywell W7100	$1,535
Motorized outdoor air damper	$ 500
Vibration control	$ 150
Ladder assembly	$ 290
Installation	
Carpentry	$1,500
Mechanical , fittings	$1,000
Electrical	$1,100
Misc.	$ 600
Sub-total	$6,675
General contracting	$1,400
Engineering	$1,000
Total Estimate	$9,075

APPENDIX 3
SECTION A3.2

Relocate the Existing System within the Building
General Description

This section details relocation of the existing system, within the existing building. The recommended areas are mechanical rooms, the outside storage room. As a secondary alternative in garbage rooms. This will require:

1. Dismantling and relocation of existing components and controls.
2. Construction of new ducting and connections from the fan location to the existing supply ducting.
3. Re-location of power wiring and disconnects.
4. Installation of outside air dampers, new discharge air controls and upgrading of duct insulation

Cost Estimate

Capital Cost equipment, controls	
Control Package - Honeywell W7100	$1,535
Motorized outdoor air damper	$ 500
Vibration control	$ 150
Installation	
Mechanical , fittings	$3,300
Electrical	$1,100
Misc.	$ 650
Contingency for chemical storage shed	$1,500
Sub-total	$8,735
General contracting	$1,840
Engineering	$1,500
Total Estimate	$12,075

APPENDIX 3
SECTION A3.3

Replace the Existing System and Locate Outside the Attic
General Description

This alternative is essentially the same as Section A3.2 with the difference that a new system will be purchased and installed.

For this alternative, the outdoor air damper and new discharge controls will be included as part of the basic air handler package.

Cost Estimate

Capital Cost equipment, controls	
Air Handling System	$9,300
c/w Controls, outdoor air damper	
Vibration control	$ 150
Installation	
Mechanical, fittings	$3,500
Electrical	$1,500
Misc.	$1,500
Sub-total	$15,950
General contracting	$3,400
Engineering	$3,000
Total	$22,350

APPENDIX 3
SECTION A3.4

Replace and Relocate, Convert to Natural Gas
General Description

This alternative is essentially the same as that of Section A3.3; the difference is that the new unit would provide heating from natural gas.

Cost Estimate

Cost from Section A5.3	$22,350
Gas fitter, Piping, chimney	$ 3,000
Total	$25,350

Estimated Savings

Operating cost savings will result if the new systems are specified to use natural gas rather than electricity. If this is done it would be preferable to tie conversion of the make-up air system to a simultaneous conversion of the domestic hot water system.

Based on a system of 2000 cfm, operation of 6 hours per day and annual heating load of 3890 deg. C. days.

Annual energy savings	$1,770

APPENDIX 4

LIFE CYCLE COST ANALYSIS
SUMMARY OF ASSUMPTIONS

1. The present value discount rate is 12%
2. Capital costs and maintenance inflate at 5% per year
3. The remaining useful life of existing systems is assumed to be 10 years,; after this it is assumed that replacement of the existing systems will be required.
4. Energy Inflation for electricity is 6%. Energy inflation for natural gas is 3% for the first 5 years and 6% thereafter.
5. Operating costs for energy are calculated, based on 6 hours daily operation. The calculation uses utility block rates for Northumberland County, effective January 1990. The actual rates, for individual facilities, will vary on a site by site basis.

APPENDIX 4, TABLE A4.1
Life Cycle Cost Analysis
Alternative 1: Relocate Existing in the Attic

Energy Rate - Electrical Consumption	$0.0445 /kWh
Energy Rate - Electrical Demand	$3.85 /kWd
Annual Energy Use	22000 kWh
Monthly Demand (Charged @ 9 months/year)	40 kW
Present Value Discount Rate	12.0%
Energy Inflation - Natural Gas	3.0%
Energy Inflation - Electricity	6.0%
Maintenance Inflation	4.0%

Twenty Year Cost Summary

	Total Costs	Present Value
Capital Cost	$45,483	$20,797
Maintenance Cost	$15,985	$5,524
Operating Cost	$94,583	$30,255
Total Cost	$156,051	$56,576

Details of Cost Summary:

Item	Immediate	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
First Cost	$9,075									
Maintenance	$500	$520	$541	$562	$585	$608	$633	$658	$684	$712
Operating	$2,365	$2,507	$2,657	$2,817	$2,986	$3,165	$3,355	$3,556	$3,769	$3,996
Total Disbursements	$11,940	$3,027	$3,198	$3,379	$3,571	$3,773	$3,987	$4,214	$4,454	$4,707
Present Value Factor	1	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	0.361
PV Capital	$9,075	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$500	$464	$431	$400	$372	$345	$321	$298	$277	$257
PV Operating	$2,365	$2,238	$2,118	$2,005	$1,898	$1,796	$1,700	$1,609	$1,522	$1,441
Present Value	$11,940	$2,703	$2,550	$2,405	$2,269	$2,141	$2,020	$1,906	$1,799	$1,697

	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19
First Cost	$36,408									
Maintenance	$740	$770	$801	$833	$866	$900	$936	$974	$1,013	$1,054
Operating	$4,235	$4,489	$4,759	$5,044	$5,347	$5,668	$6,008	$6,368	$6,751	$7,156
Total Disbursements	$41,384	$5,259	$5,559	$5,877	$6,213	$6,568	$6,944	$7,342	$7,763	$8,209
Present Value Factor	0.322	0.287	0.257	0.229	0.205	0.183	0.163	0.146	0.130	0.116
PV Capital	$11,722	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$238	$221	$205	$191	$177	$165	$153	$142	$132	$122
PV Operating	$1,364	$1,291	$1,221	$1,156	$1,094	$1,035	$980	$928	$878	$831
Present Value	$13,324	$1,512	$1,427	$1,347	$1,271	$1,200	$1,133	$1,069	$1,010	$953

APPENDIX 4, TABLE A4.2
Life Cycle Cost Analysis
Alternative 2: Relocate Existing outside the Attic

Energy Rate - Electrical Consumption	$0.0445 /kWh
Energy Rate - Electrical Demand	$3.85 /kWd
Annual Energy Use	22000 kWh
Monthly Demand (Charged @ 9 months/year)	40 kW
Present Value Discount Rate	12.0%
Energy Inflation - Natural Gas	3.0%
Energy Inflation - Electricity	6.0%
Maintenance Inflation	4.0%

Twenty Year Cost Summary

	Total Costs	Present Value
Capital Cost	$48,483	$23,797
Maintenance Cost	$15,985	$5,524
Operating Cost	$94,583	$30,255
Total Cost	$159,051	$59,576

Details of Cost Summary:

Item	Immediate	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
First Cost	$12,075									
Maintenance	$500	$520	$541	$562	$585	$608	$633	$658	$684	$712
Operating	$2,365	$2,507	$2,657	$2,817	$2,986	$3,165	$3,355	$3,556	$3,769	$3,996
Total Disbursements	$14,940	$3,027	$3,198	$3,379	$3,571	$3,773	$3,987	$4,214	$4,454	$4,707
Present Value Factor	1	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	0.361
PV Capital	$12,075	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$500	$464	$431	$400	$372	$345	$321	$298	$276	$257
PV Operating	$2,365	$2,238	$2,118	$2,005	$1,898	$1,796	$1,700	$1,609	$1,522	$1,441
Present Value	$14,940	$2,703	$2,550	$2,405	$2,269	$2,141	$2,020	$1,906	$1,799	$1,697

	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19
First Cost	$36,408									
Maintenance	$740	$770	$801	$833	$866	$900	$936	$974	$1,013	$1,053
Operating	$4,235	$4,489	$4,759	$5,044	$5,347	$5,668	$6,008	$6,368	$6,751	$7,156
Total Disbursements	$41,384	$5,259	$5,559	$5,877	$6,213	$6,568	$6,944	$7,342	$7,763	$8,209
Present Value Factor	0.322	0.287	0.257	0.229	0.205	0.183	0.163	0.146	0.130	0.116
PV Capital	$11,722	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$238	$221	$205	$191	$177	$165	$153	$142	$132	$122
PV Operating	$1,364	$1,291	$1,221	$1,156	$1,094	$1,035	$980	$928	$878	$831
Present Value	$13,324	$1,512	$1,427	$1,347	$1,271	$1,200	$1,133	$1,069	$1,010	$953

APPENDIX 4, TABLE A4.3
Life Cycle Cost Analysis
Alternative 2: Replace and Relocate Outside the Attic

Energy Rate - Electrical Consumption	$0.0445 /kWh
Energy Rate - Electrical Demand	$3.85 /kWd
Annual Energy Use	22000 kWh
Monthly Demand (Charged @ 9 months/year)	40 kW
Present Value Discount Rate	12.0%
Energy Inflation - Natural Gas	3.0%
Energy Inflation - Electricity	6.0%
Maintenance Inflation	4.0%

Twenty Year Cost Summary

	Total Costs	Present Value
Capital Cost	$22,350	$22,350
Maintenance Cost	$15,985	$5,524
Operating Cost	$94,583	$30,255
Total Cost	$132,917	$58,129

Details of Cost Summary:

Item	Immediate	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
First Cost	$22,350									
Maintenance	$500	$520	$541	$562	$585	$608	$633	$658	$684	$712
Operating	$2,365	$2,507	$2,657	$2,817	$2,986	$3,165	$3,355	$3,556	$3,769	$3,996
Total Disbursements	$25,215	$3,027	$3,198	$3,379	$3,571	$3,773	$3,987	$4,214	$4,454	$4,707
Present Value Factor	1	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	0.361
PV Capital	$22,350	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$500	$464	$431	$400	$372	$345	$321	$298	$276	$257
PV Operating	$2,365	$2,238	$2,118	$2,005	$1,898	$1,796	$1,700	$1,609	$1,522	$1,441
Present Value	$25,215	$2,703	$2,550	$2,405	$2,269	$2,141	$2,020	$1,906	$1,799	$1,697

	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19
First Cost										
Maintenance	$740	$770	$801	$833	$866	$900	$936	$974	$1,013	$1,053
Operating	$4,235	$4,489	$4,759	$5,044	$5,347	$5,668	$6,008	$6,368	$6,751	$7,156
Total Disbursements	$4,975	$5,259	$5,559	$5,877	$6,213	$6,568	$6,944	$7,342	$7,763	$8,209
Present Value Factor	0.322	0.287	0.257	0.229	0.205	0.183	0.163	0.146	0.130	0.116
PV Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$238	$221	$205	$191	$177	$165	$153	$142	$132	$122
PV Operating	$1,364	$1,291	$1,221	$1,156	$1,094	$1,035	$980	$928	$878	$831
Present Value	$1,602	$1,512	$1,427	$1,347	$1,271	$1,200	$1,133	$1,069	$1,010	$953

APPENDIX 4, TABLE A4.4
Life Cycle Cost Analysis
Alternative 4: Replace and Relocate with Conversion to Gas

Energy Rate - Natural gas	$0.2180 /MΔ3
Annual Energy Use	22000 kWh
Monthly Demand (Charged @ 9 months/year)	40 kW
Present Value Discount Rate	12.0%
Energy Inflation - Natural Gas	3.0%
Energy Inflation - Electricity	6.0%
Maintenance Inflation	4.0%

Twenty Year Cost Summary:

	Total Costs	Present Value
Capital Cost	$25,350	$25,350
Maintenance Cost	$15,985	$5,524
Operating Cost	$23,218	$7,580
Present Value - Total Cost	$64,553	$38,453

Details of Cost Summary:

Item	Immediate	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
First Cost	$25,350									
Maintenance	$500	$520	$541	$562	$585	$608	$633	$658	$684	$712
Operating	$662	$682	$702	$723	$745	$767	$814	$862	$914	$969
Total Disbursements	$26,512	$1,202	$1,243	$1,286	$1,330	$1,376	$1,446	$1,520	$1,598	$1,681
Present Value Factor	1	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	0.361
PV Capital	$25,350	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$500	$464	$431	$400	$372	$345	$321	$298	$276	$257
PV Operating	$662	$609	$560	$515	$474	$435	$412	$390	$369	$349
Present Value	$26,512	$1,073	$991	$915	$845	$781	$733	$688	$646	$606

	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19
First Cost										
Maintenance	$740	$770	$801	$833	$866	$900	$936	$974	$1,013	$1,053
Operating	$1,027	$1,089	$1,154	$1,223	$1,297	$1,374	$1,457	$1,544	$1,637	$1,735
Total Disbursements	$1,767	$1,858	$1,955	$2,056	$2,162	$2,275	$2,393	$2,518	$2,650	$2,789
Present Value Factor	0.322	0.287	0.257	0.229	0.205	0.183	0.163	0.146	0.130	0.116
PV Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$238	$221	$205	$191	$177	$165	$153	$142	$132	$122
PV Operating	$331	$313	$296	$280	$265	$251	$238	$225	$213	$201
Present Value	$569	$534	$502	$471	$442	$416	$390	$367	$345	$324

APPENDIX 5

PRODUCT LITERATURE

APPENDIX 4, TABLE A4.1
Life Cycle Cost Analysis
Alternative 1: Relocate Existing in the Attic

Energy Rate - Electrical Consumption	$0.0445 /kWh
Energy Rate - Electrical Demand	$3.85 /kWd
Annual Energy Use	22000 kWh
Monthly Demand (Charged @ 9 months/year)	40 kW
Present Value Discount Rate	12.0%
Energy Inflation - Natural Gas	3.0%
Energy Inflation - Electricity	6.0%
Maintenance Inflation	4.0%

Twenty Year Cost Summary

	Total Costs	Present Value
Capital Cost	$45,483	$20,797
Maintenance Cost	$15,985	$5,524
Operating Cost	$94,583	$30,255
Total Cost	$156,051	$56,576

Details of Cost Summary:

Item	Immediate	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
First Cost	$9,075									
Maintenance	$500	$520	$541	$562	$585	$608	$633	$658	$684	$712
Operating	$2,365	$2,507	$2,657	$2,817	$2,986	$3,165	$3,355	$3,557	$3,769	$3,995
Total Disbursements	$11,940	$3,027	$3,198	$3,379	$3,571	$3,773	$3,987	$4,216	$4,453	$4,707
Present Value Factor	1	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	0.361
PV Capital	$9,075	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$500	$464	$431	$400	$372	$345	$321	$298	$276	$257
PV Operating	$2,365	$2,238	$2,118	$2,005	$1,898	$1,796	$1,700	$1,609	$1,523	$1,441
Present Value	$11,940	$2,703	$2,550	$2,405	$2,269	$2,141	$2,020	$1,906	$1,799	$1,698

	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19
First Cost	$36,408									
Maintenance	$740	$770	$801	$833	$866	$901	$937	$975	$1,014	$1,055
Operating	$4,235	$4,489	$4,759	$5,044	$5,347	$5,668	$6,008	$6,369	$7,751	$7,156
Total Disbursements	$41,384	$5,259	$5,559	$5,877	$6,213	$6,568	$6,944	$7,342	$8,765	$8,210
Present Value Factor	0.322	0.287	0.257	0.229	0.205	0.183	0.163	0.146	0.130	0.116
PV Capital	$11,722	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$238	$221	$205	$191	$177	$165	$153	$142	$131	$122
PV Operating	$1,364	$1,291	$1,221	$1,156	$1,094	$1,035	$980	$927	$1,141	$830
Present Value	$13,324	$1,512	$1,427	$1,347	$1,271	$1,200	$1,133	$1,069	$1,272	$952

APPENDIX 4, TABLE A4.2
Life Cycle Cost Analysis
Alternative 2: Relocate Existing outside the Attic

Energy Rate - Electrical Consumption	$0.0445 /kWh
Energy Rate - Electrical Demand	$3.85 /kWd
Annual Energy Use	22000 kWh
Monthly Demand (Charged @ 9 months/year)	40 kW
Present Value Discount Rate	12.0%
Energy Inflation - Natural Gas	3.0%
Energy Inflation - Electricity	6.0%
Maintenance Inflation	4.0%

Twenty Year Cost Summary

	Total Costs	Present Value
Capital Cost	$48,483	$23,797
Maintenance Cost	$15,985	$5,524
Operating Cost	$94,583	$30,255
Total Cost	$159,051	$59,576

Details of Cost Summary:

Item	Immediate	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
First Cost	$12,075									
Maintenance	$500	$520	$541	$562	$585	$608	$633	$658	$685	$712
Operating	$2,365	$2,507	$2,657	$2,817	$2,986	$3,165	$3,355	$3,557	$3,770	$3,997
Total Disbursements	$14,940	$3,027	$3,198	$3,379	$3,571	$3,773	$3,987	$4,214	$4,454	$4,707
Present Value Factor	1	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	0.361
PV Capital	$12,075	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$500	$464	$431	$400	$372	$345	$321	$298	$277	$257
PV Operating	$2,365	$2,238	$2,118	$2,005	$1,898	$1,796	$1,700	$1,609	$1,523	$1,441
Present Value	$14,940	$2,703	$2,550	$2,405	$2,269	$2,141	$2,020	$1,906	$1,800	$1,698

	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19
First Cost	$36,408									
Maintenance	$740	$770	$801	$833	$866	$901	$937	$974	$1,013	$1,054
Operating	$4,235	$4,489	$4,759	$5,044	$5,347	$5,668	$6,008	$6,369	$6,751	$7,156
Total Disbursements	$41,384	$5,259	$5,559	$5,877	$6,213	$6,568	$6,944	$7,343	$7,764	$8,210
Present Value Factor	0.322	0.287	0.257	0.229	0.205	0.183	0.163	0.146	0.130	0.116
PV Capital	$11,722	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$238	$221	$205	$191	$177	$165	$153	$142	$132	$122
PV Operating	$1,364	$1,291	$1,221	$1,156	$1,094	$1,035	$980	$927	$877	$830
Present Value	$13,324	$1,512	$1,427	$1,347	$1,271	$1,200	$1,133	$1,069	$1,009	$952

APPENDIX 4, TABLE A4.3
Life Cycle Cost Analysis
Alternative 2: Replace and Relocate Outside the Attic

Energy Rate - Electrical Consumption	$0.0445 /kWh
Energy Rate - Electrical Demand	$3.85 /kWd
Annual Energy Use	22000 kWh
Monthly Demand (Charged @ 9 months/year)	40 kW
Present Value Discount Rate	12.0%
Energy Inflation - Natural Gas	3.0%
Energy Inflation - Electricity	6.0%
Maintenance Inflation	4.0%

Twenty Year Cost Summary

	Total Costs	Present Value
Capital Cost	$22,350	$22,350
Maintenance Cost	$15,985	$5,524
Operating Cost	$94,583	$30,255
Total Cost	$132,917	$58,129

Details of Cost Summary:

Item	Immediate	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
First Cost	$22,350									
Maintenance	$500	$520	$541	$562	$585	$608	$632	$657	$684	$711
Operating	$2,365	$2,507	$2,657	$2,817	$2,986	$3,165	$3,355	$3,557	$3,770	$3,996
Total Disbursements	$25,215	$3,027	$3,198	$3,379	$3,571	$3,773	$3,987	$4,214	$4,454	$4,707
Present Value Factor	1	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	0.361
PV Capital	$22,350	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$500	$464	$431	$400	$372	$345	$321	$298	$277	$257
PV Operating	$2,365	$2,238	$2,118	$2,005	$1,898	$1,794	$1,700	$1,608	$1,523	$1,441
Present Value	$25,215	$2,703	$2,550	$2,405	$2,269	$2,141	$2,020	$1,906	$1,800	$1,698

	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19
First Cost										
Maintenance	$740	$770	$801	$833	$866	$901	$937	$975	$1,014	$1,055
Operating	$4,235	$4,489	$4,759	$5,044	$5,347	$5,668	$6,008	$6,369	$6,751	$7,156
Total Disbursements	$4,975	$5,259	$5,559	$5,877	$6,213	$6,568	$6,944	$7,343	$7,765	$8,211
Present Value Factor	0.322	0.287	0.257	0.229	0.205	0.183	0.163	0.146	0.130	0.116
PV Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$238	$221	$205	$191	$177	$165	$153	$142	$132	$122
PV Operating	$1,364	$1,291	$1,221	$1,156	$1,094	$1,035	$980	$927	$878	$831
Present Value	$1,602	$1,512	$1,427	$1,347	$1,271	$1,200	$1,133	$1,069	$1,010	$953

APPENDIX 4, TABLE A4.4
Life Cycle Cost Analysis
Alternative 4: Replace and Relocate with Conversion to Gas

Energy Rate - Natural gas	$0.2180 /MΔ3
Annual Energy Use	22000 kWh
Monthly Demand (Charged @ 9 months/year)	40 kW
Present Value Discount Rate	12.0%
Energy Inflation - Natural Gas	3.0%
Energy Inflation - Electricity	6.0%
Maintenance Inflation	4.0%

Twenty Year Cost Summary:

	Total Costs	Present Value
Capital Cost	$25,350	$25,350
Maintenance Cost	$15,985	$5,524
Operating Cost	$23,218	$7,580
Present Value - Total Cost	$64,553	$38,453

Details of Cost Summary:

Item	Immediate	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
First Cost	$25,350									
Maintenance	$500	$520	$541	$562	$585	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Operating	$662	$682	$702	$723	$745	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Disbursements	$26,512	$1,202	$1,243	$1,286	$1,330	$1,376	$1,424	$1,[illegible]	$1,[illegible]	$1,[illegible]
Present Value Factor	1	0.893	0.797	0.712	0.636	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PV Capital	$25,350	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$500	$464	$431	$400	$372	$345	$321	$[illegible]	$[illegible]	$[illegible]
PV Operating	$662	$609	$560	$515	$474	$436	$401	$[illegible]	$[illegible]	$[illegible]
Present Value	$26,512	$1,073	$991	$915	$846	$781	$722	$[illegible]	$[illegible]	$[illegible]

	Year 10	Year 11	Year 12	Year 13	Year 14	Year [illegible]	Year [illegible]	Year [illegible]	Year [illegible]	Year [illegible]
First Cost										
Maintenance	$740	$770	$801	$833	$866	$[illegible]	$[illegible]	$[illegible]	$1,[illegible]	$1,[illegible]
Operating	$1,027	$1,089	$1,154	$1,223	$1,297	$1,[illegible]	$1,[illegible]	$1,[illegible]	$1,[illegible]	$1,[illegible]
Total Disbursements	$1,767	$1,858	$1,955	$2,056	$2,162	$2,[illegible]	$2,[illegible]	$2,[illegible]	$3,[illegible]	$3,[illegible]
Present Value Factor	0.322	0.287	0.257	0.229	0.205	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PV Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
PV Operating	$238	$221	$205	$191	$177	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]
PV Operating	$331	$313	$296	$280	$265	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]
Present Value	$569	$534	$501	$471	$442	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]

APPENDIX 5

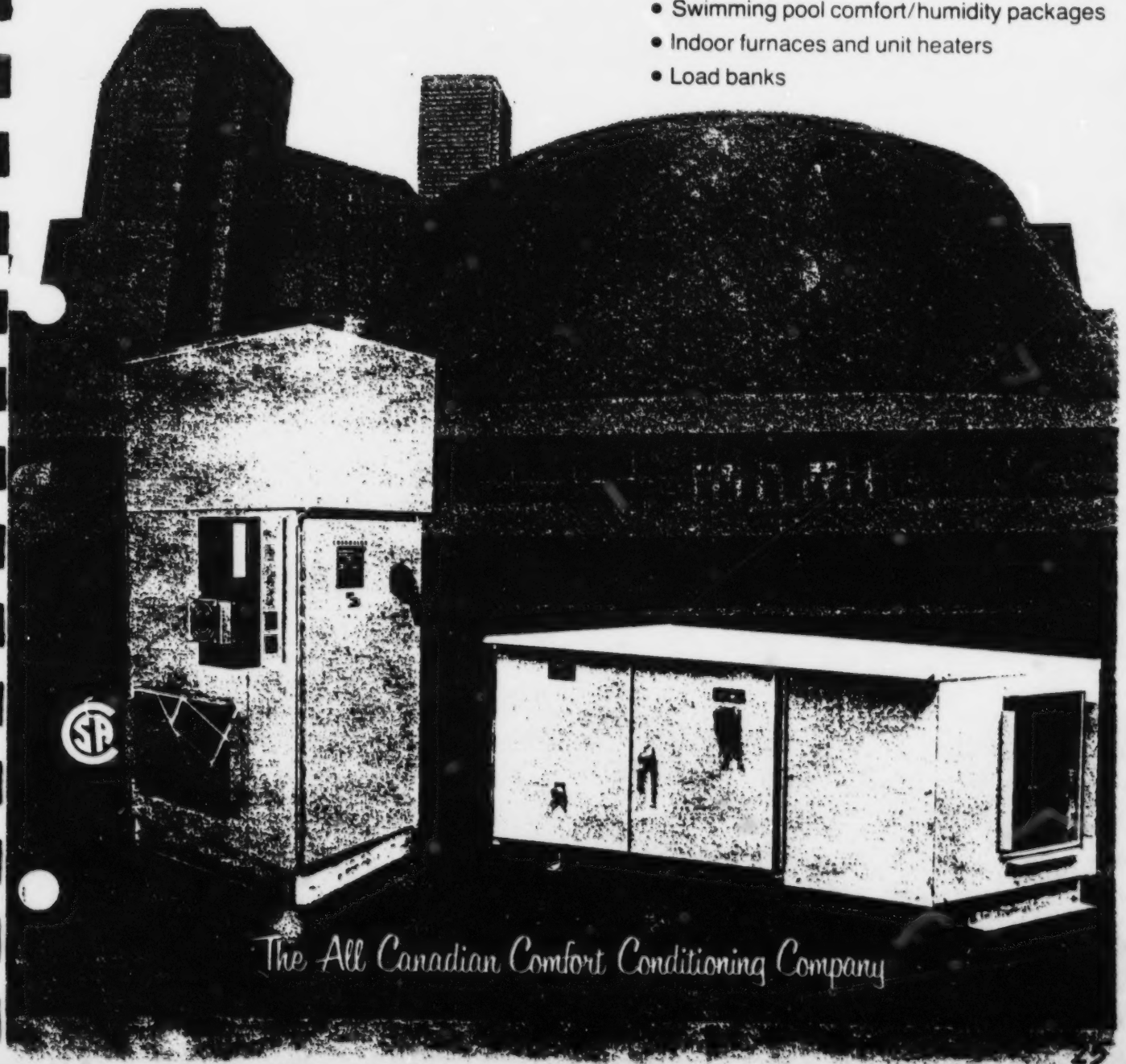
PRODUCT LITERATURE

CHROMALOX

PACKAGED ELECTRIC HEATING/VENTILATING UNITS — SERIES HAV

Designed and built in Canada for use as:

- Rooftop make-up air units
- Indoor make-up air units
- Heating and ventilating units
- Swimming pool comfort/humidity packages
- Indoor furnaces and unit heaters
- Load banks



1 CHROMALOX SERIES HAV HEATING/VENTILATING UNITS

- Designed and built in Canada for Canadian requirements
- Ruggedly constructed of heavy gauge steel
- Engineered units easily adapted to design requirements with large selection of built in accessories
- Factory prewired, assembled and tested to allow simple field installation
- Offer an excellent degree of controlability and indication of operating mode in all control levels
- Specialized devices, beyond the typical optional features listed, may be incorporated into any Chromalox series HAV unit to match the owners perference.
- Consult the factory for enginnering and pricing data on unlisted options

2 CHROMALOX SERIES HAV HEATING/VENTILATING UNITS

- Offer 4 standard size packages
- Are available in all voltages up to 600 volts, 1 Ø or 3 Ø
- Provide temperature rises up to 120° F (67° C)
- Are complete with prewired control panel with door interlocked disconnect switch
- Are available with
  - built-in filters
  - insulated cabinetry
  - shut-off dampers
  - prewired damper motor
  - mixing box
  - inlet cowl with birdscreen

3 TO SELECT CHROMALOX SERIES HAV HEATING/VENTILATING UNITS

- Calculate or determine from plans & specifications the design air flow rate, the external static pressure, the kW heating capacity and the supply voltage and phase
- Using physical data table on page 5, determine the minimum size of HAV unit which can provide the kW heating capacity
- Using HAV performance curves on page 8, check to see if the selected HAV size can provide the required air flow rate against the expected external static pressure
- Select a Chromalox control level for the intended application

  The table on page 4 summarizes typical unit applications and suggested control levels

  Chromalox control levels are discussed on page 7

4 TO SPECIFY OR ORDER CHROMALOX SERIES HAV HEATING/ VENTILATING UNITS BEST SUITED FOR THE APPLICATION

Complete the typical specification shown on page 5, using the calculations and selection criteria obtained in section 4 above.

NOTE: For most applications the significant choices for each major component are contained within the horizontal colour keyed groups extending from the specification through page 4.

If any specialized devices, beyond the optional features listed for normal consideration, are required, these devices should be included in the specification.

Contact your nearest Chromalox sales office for assistance in specifying or ordering an HAV unit.

Typical HAV Unit Construction Detail

- All units are custom designed for individual applications
- Components shown may not be required in all applications intended for this unit

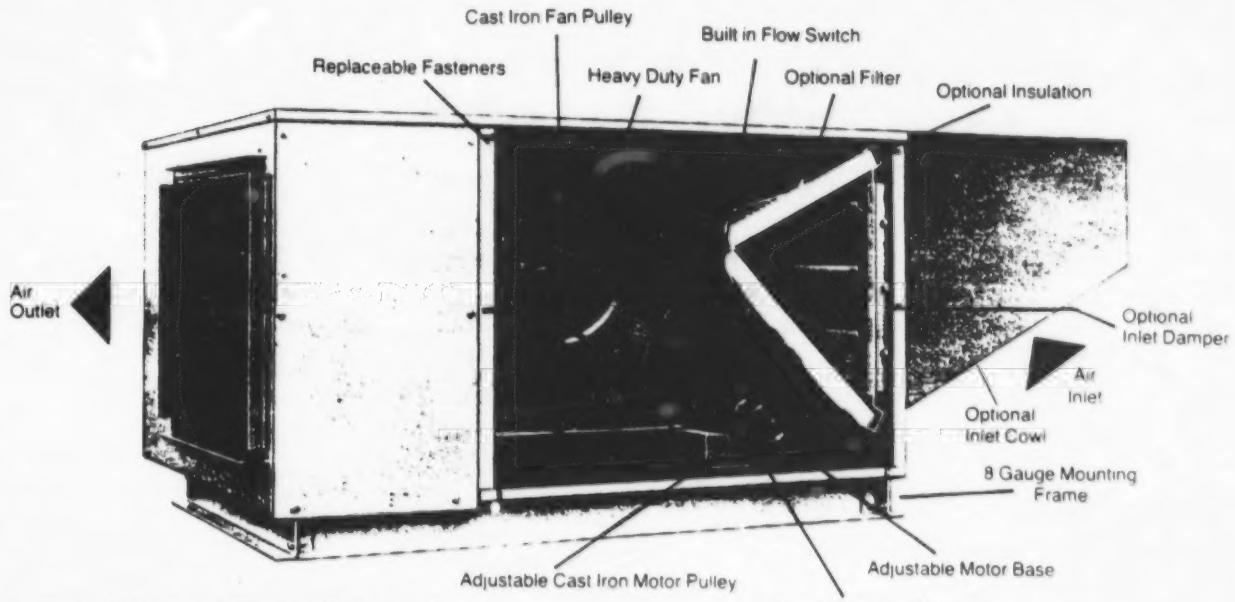


Figure 1 HAV-18 Shown with Fan and Filter Access Door Removed

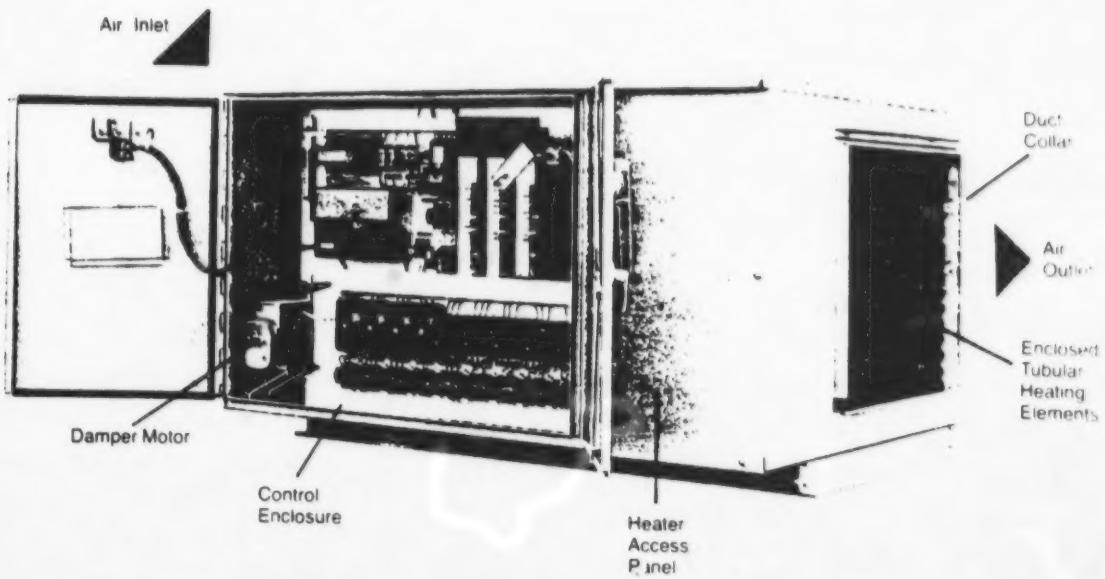


Figure 2 HAV-18 unit featuring Level 5 control system

UNIT HEATERS				MAKE-UP AIR UNITS							
UNDUCTED SYSTEM		DUCTED SYSTEM		ROOFTOP UNIT		INDOOR UNIT	OUTLET AIR TEMPERATURE VARIATION			HEATING & VENTILATING UNITS	SWIMMING POOL PACKAGE	LOAD BANKS
UNPOPULATED	POPULATED	UNPOPULATED	POPULATED				±8°F	±5°F	±2°F			
O	O	O	O	S	NR					NR	NR	S
NR	NR	NR	NR	S	NR					O	O	O
O	O	O	O	O	O					O	O	O
S	S	S	S	S	S					S	S	S
S	S	S	S	S	S					S	S	S
S	S	S	S	S	S					S	S	S
O	O	O	O	O	O					O	O	O
S	S	S	S	S	S					S	S	S
O	O	O	O	O	O					O	O	O
NR	NR	NR	NR	R	O					NR	NR	NR
NR	NR	NR	NR	NR	NR					O	O	NR
S	S	S	S	NR	S					S	S	S
S	S	S	S	S	S					S	S	O
G	M	G	M			U	U	U	U	U		
G	M	M	U			U	U	U	U	U		
G	G	G	G			U	U	U	U	U		
M	U	U	U			U	U	U	U	U		
M	U	U	U			G	M	U	U	U		
G	G	G	G			E	M	U	G	G		
E	G	E	G			U	U	U	G	M		
U	U	U	U			E	E	E	E	E		
E	E	E	E			E	E	E	E	E		
E	E	E	E			E	E	E	E	E		
E	E	E	E			E	E	E	E	E		

Features

APPLICATION
- * Specify indoor or outdoor installation
- – Factory prewired, assembled and tested
- * Specify application

ENCLOSURE:
- * Uninsulated (unit heaters & rooftop units)
- * Weatherproof construction (for outdoor units)
- * Inlet cowl & birdscreen (rooftop units)
- ** Specify special paint finish if required
- ** Specify special mounting arrangements

BLOWER FAN
- Heavy duty, forward curved, blowers with keyed shafts
- Dynamically balanced, galvanized fan wheels
- Ball bearings, suitable for -65°F to +250°F

BLOWER DRIVES:
- – Cast iron pulleys, with single "B" belt drives
- – Adjustable motor pulley, keyweyed shafts

FAN MOTOR
- Totally enclosed motor, with sealed ball bearings
- Rail mounting base, for easy belt tension adjustment
- Operates at supply voltage and phase
- ** Specify optional motor if required

HEATING SECTION:
- – [illegible]coated, finned steel tubular sheathed elements
- ** Incoloy sheated tubular elements
- – Built in overtemperature protection circuits

FILTERS: (optional)
- * Disposable, medium efficiency, 2 inch filters
- ** Special filters if required

CLOSE OFF DAMPERS: (optional)
- * All aluminum damper, with PVC seals
- * Spring return damper motor, mounted inside enclosure
- – Damper closes on power failure or shutdown

MIXING CHAMBER: (optional)
- * Factory attached with built in damper sections
- * Specify either parallel or opposed blade dampers
- * Specify either 2 position or proportioning damper motor
- – Insulated, heavy gauge mixing box cabinetry
- * Specify damper locations, see figure 9 on page 9

CONTROL PANEL:
- – Cams-12, double door enclosure, with inner-panel
- – Door interlocked disconnect switch and splitter
- – Fused control circuit (transformer as required)
- – Magnetic contactors, with overcurrent protection
- – Magnetic motor starter with overcurrent protection
- – On/off selector switch
- – Delay off timer (dissipates residual heat)
- – Unit mounted air flow switch
- – Terminals for:
  - I) Remote on/off switch
  - II) Remote fire alarm shutdown interlock
  - III) Thermostat connections
  - IV) Other specified devices

LEVEL OF CONTROL
- * Level # 1 c/w wall mounted thermostat
- * Level # 1 c/w unit mounted thermostat
- * Level # 2 c/w wall mounted thermostat
- * Level # 2 c/w unit mounted thermostat
- * Level # 3
- * Level # 4
- * Level # 5
- * Level # 6
- * Level # 7
- * Level # 8
- * Level # 9

LEGEND:
- S Standard feature
- O Optional feature
- NR Not normally required
- R Required normally
- E Excellent
- G Good
- M Minimal
- U Unsatisfactory

System performance and versatility rating
- – Standard feature
- * Specify feature if required
- ** [illegible]

Typical Specification

Provide and install where shown on plan _____ Chromalox TYPE HAV- _____ Packaged Electric Air Handling Unit(s), rated _____ volts, _____ phase, 60 cycle, _____ Kilowatts, designed to continuously deliver _____ cfm against an external static pressure of _____ inches water column.

Each Unit shall be a factory prewired assembly, suitable for indoor*/outdoor* mounting, and shall consist of the following major components.

1. [illegible] cabinet enclosure of cold rolled steel, painted grey [illegible] mounted and attached to an 8 gauge formed channel steel skid. (Insulation to be high density, glass fibre neoprene coated.)

2. Double inlet blower, with forward curved fan wheels and ball bearings.

3. Single "B" belt, cast iron adjustable drive pulley and cast iron blower pulley, on keyseyed shafts.

4. Conservatively sized, totally enclosed fan motor, with ball bearings. Heavy duty motor base and belt tensioner.

5. Ceramic Coated, finned tubular, steel sheathed heating elements.

6. 2 inch thick, disposable, medium efficiency, filters.

7. Shut-off damper, with two position, spring return damper motor. To close on shutdown or power failure.

8. Factory attached mixing chamber, with proportioning*/two position parallel*/opposed dampers, with the outdoor air inlet located on _____ of mixing box, and indoor air inlet located on _____ of mixing box (control integral).

9. Attached CEMA-12*/CEMA-3 control panel, complete with:
   a) unfused door interlocked disconnect switch and splitter,
   b) fused control circuit (transformer as required)
   c) magnetic contactors with overcurrent protection,
   d) magnetic motor starter with overcurrent protection,
   e) on/off selector switch,
   f) delay off timer,
   g) unit mounted air flow switch,
   h) terminals for: i) Remote on/off switch,
      ii) remote fire alarm shutdown switch,
      iii) thermostat connections.

10. CHROMALOX LEVEL # Control System, complete with,
    a) heating stages (specify for levels 2 to 5 only)
    b) integral*/remote temperature controller.

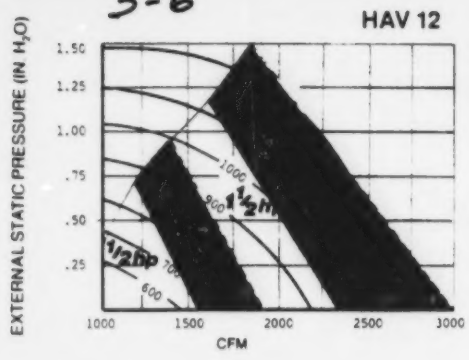
*Select one of two choices shown

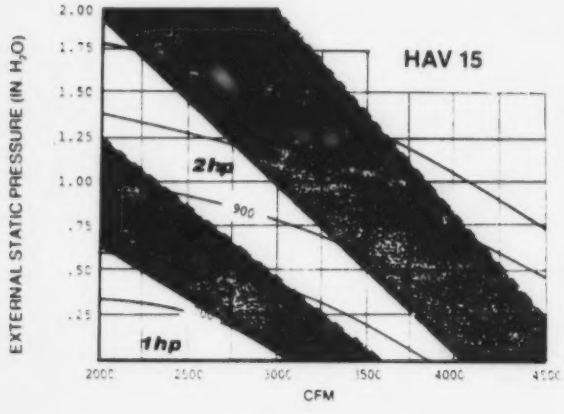
Physical Data

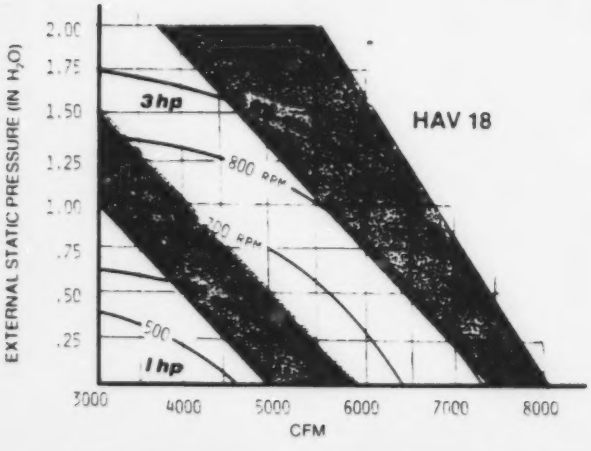
Model Number:		HAV 12	HAV 15	HAV 18	HAV 22
Minimum CFM		1600	2000	3600	6000
Maximum CFM		2800	4000	7000	18000
Max. external S.P.		1.25 in SWG (312 Pa)	1.5 in SWG (375 Pa)	1.75 in SWG (436 Pa)	1.75 in SWG (436 Pa)
Maximum Kilowatts		90	150	240	450
Max. disconnect size		200 amps	400 amps	600 amps	1000 amps
Maximum line Amps		180	320	480	800
Voltages available		208 to 600	208 to 600	208 to 600	416 to 600
Phase		1 or 3	1 or 3	1 or 3	3 only
Max. discharge temp		140°F(60°C)	140 F(60 C)	140°F(60°C)	140 F(60 C)
Max. temp. rise		120°F(67°C)	120 F(67 C)	120°F(67°C)	120 F(67 C)
Heating stages avail		1, 2, 3 or 6	1, 2, 4 or 8	1, 2, 5 or 10	1, 2, 3, 6 or 12
Cabinetry Gauge		16 ga.	14 ga	14 ga.	12 ga
Frame gauge (skid)		8 ga.	8 ga	8 ga.	8 ga
Fan wheel diameter		12 inch	15 inch	18 inch	22 inch
Motor size range		½ to 2 hp	1 to 3 hp	1 to 5 hp	5 to 15 hp
Motor starter size		cema 00	cema 00.0	cema 00 to 1	cema 0 to 2
Motor voltage		Line	Line	Line	Line
Filters. Qty./Size in		1-24 x 24 x 2	2-20 x 20 x 2 2-16 x 20 x 2	1-16 x 20 x 2 3-20 x 25 x 2	12-20 x 25 x 2
Filter type (standard)		Medium eff. disposable	Medium eff. disposable	Medium eff. disposable	Medium eff. disposable
Optional filter type		Replaceable media	Replaceable media	Replaceable media	Replaceable media
Weight lbs. (Kg.)		730(340)	1250(570)	1600(730)	2400 (1100)
Dimensions inches (mm)					
Outlet width	A	18(457)	30(762)	36(914)	48(1219)
Outlet height	B	18(457)	24(610)	28(711)	42(1067)
Inlet width	C	21(533)	32(813)	38(965)	57(1448)
Inlet height	D	14(356)	16(406)	22(559)	30(762)
Frame width	E	24(610)	35(889)	41(1041)	60(1524)
	F	1½(38)	1½(38)	1½(38)	1½(38)
Mix box length	G	24(610)	30(762)	30(762)	48(1219)
Overall height	H	29½(734)	34½(876)	40½(1029)	54½(1384)
Edge inlet cowl	J	10(254)	10(254)	10(254)	15(381)
Edge inlet cowl	K	18(457)	23(584)	29(737)	36(914)
Length basic unit	L	62(1575)	62(1575)	68(1727)	92(2340)
Inlet cowl length	M	24(610)	24(610)	30(762)	36(914)
Roof to top inlet	N	2(51)	5(127)	5(127)	4(102)
Mix box height	P	24(610)	30(762)	36(914)	50(1270)
Outlet above floor	R	7(178)	7(178)	8(203)	8(203)
Overall width	W	37½(953)	48½(1232)	56½(1435)	75½(1918)
	X	3(76)	3(76)	4(103)	4(103)
Flange width	Y	2(51)	2(51)	2(51)	2(51)
Service area	Z	24(610)	24(610)	24(610)	36(914)

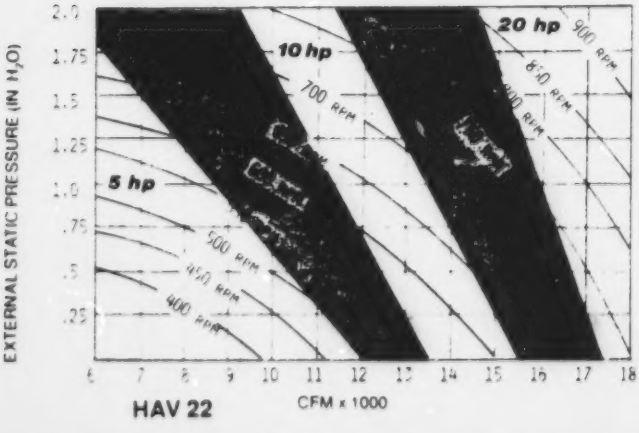
5-6

HAV Performance Curves









Heating Capacity

$$kW = \frac{cfm \times \triangle t}{3200}$$

where $\triangle t$ = temp rise in F

derived from $Q = \frac{1.08 \times cfm \times \triangle t}{3412}$

1 kWh = 3412 Btu

Line Current

$$I = \frac{kW \times 1000}{V \times 1.73}$$ for 3 ϕ supply

$$I = \frac{kW \times 1000}{V}$$ for 1 ϕ supply

Air Mixing Equations

$$t_m = \frac{(cfm_{oa} \times t_{oa}) + (cfm_{ra} \times t_{rm})}{cfm_{sa}}$$

$$h_m = \frac{(cfm_{oa} \times h_{oa}) + (cfm_{ra} \times h_{rm})}{cfm_{sa}}$$

$$W_m = \frac{(cfm_{oa} \times W_{oa}) + (cfm_{ra} \times W_{rm})}{cfm_{sa}}$$

where:

t_m = Mix dry bulb temperature
h_m = Mix enthalpy
W_m = Mix moisture content
cfm_{oa} = cfm outdoor air
cfm_{ra} = cfm return air
cfm_{sa} = cfm supply air
t_{oa} = Temperature outside air
t_{rm} = Temperature room

Conversion Factors for S.I. units

Quantity (Symbol)	S.I. Symbol (Units)	Conversion Factors
length (l)	m (metre) cm (centimetre) mm (millimetre)	1 foot = 0.3048 m 1 inch = 0.254 cm 1 inch = 25.4 mm
area (A)	m^2 (square metre)	1 square foot = 0.0929 m^2
volume (V)	m^3 (cubic metre)	1 cubic foot = 0.0283 m^3
time (t)	s (second)	1 minute = 60 sec.
flow (Q)	m^3/s	1 cfm = 0.000472 m^3/s
velocity (V)	m/s	1 foot per minute = 0.00508 m/s
frequency	Hz (hertz)	1 cycle = 1 Hz
mass (m)	kg (Kilogram)	1 pound = 0.454 kg
density	kg/m^3	1 lb/ft^3 = 16.02 kg/m^3
pressure (p)	Pa (pascal)	1 inch of water = 249.1 Pa 1 psi = 6.895 Pa
work (w)	J (joule)	1 kilowatt hour = 3.6 MJ
power (P)	W (watt)	1 horsepower = 746 W
Celsius temperature (t)	°C (degree Celsius)	°F = 1.8°C + 32
Heat (Q)	J (joule)	1 Btu = 1055.06 J 1 watt hour = 3600 J
heat flow rate (q)	W (watt)	1 Btu per hr = 0.293071 W

Common S.I. Prefixes	Symbol	Multiplying Factor
mega	M	10^6 (1,000,000)
kilo	k	10^3 (1,000)
centi	c	10^{-2} (0.01)
milli	m	10^{-3} (0.001)

Outline Dimensions

Indoor units

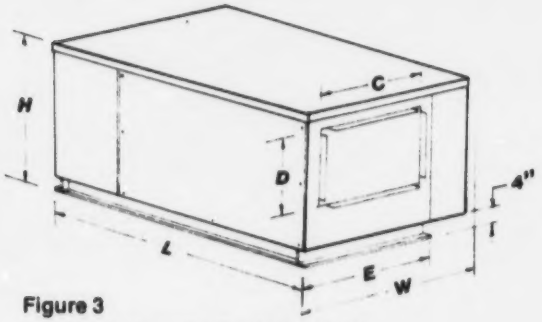


Figure 3
Basic unit showing air inlet and fan and filter access

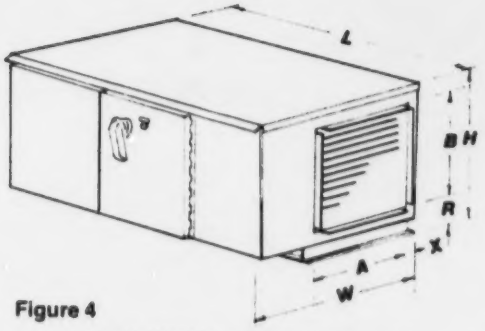
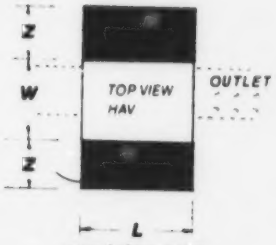


Figure 4
Basic HAV showing control panel and air outlet



servicing area required

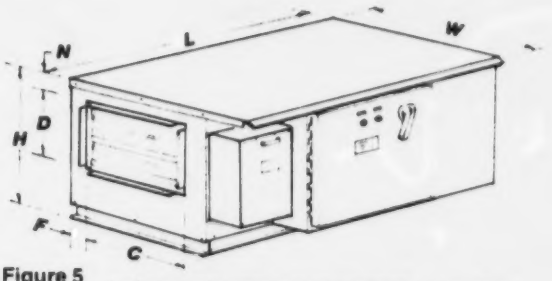


Figure 5
indoor unit with attached SCR controller* with shut-off damper

*SCR must be mounted in warm and dry location

Rooftop units

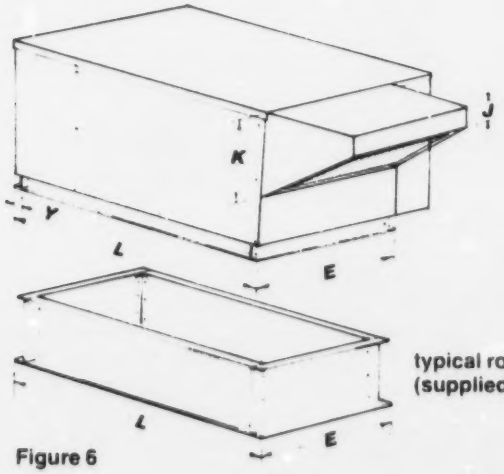


Figure 6
typical roof curb (supplied by others)

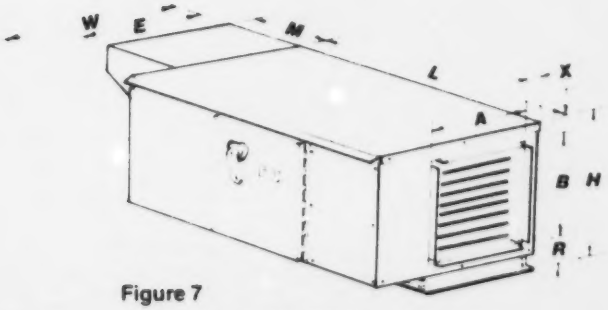
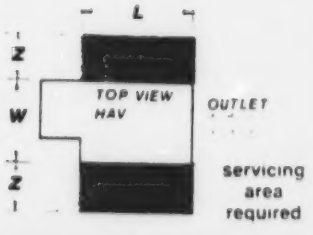
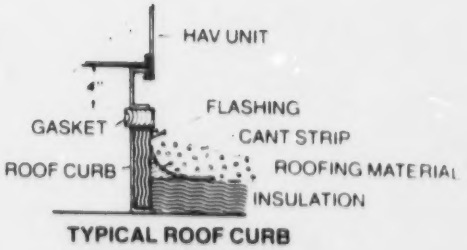


Figure 7
View of control panel and outlet



servicing area required



TYPICAL ROOF CURB
(supplied by others)

Control Level Requirements

The degree of temperature control required varies with the application. The control level requirements described below have been found suitable for most applications in Canada. The degree and precision of control increases with an increase in level, however, the system cost may be less in some cases, for a higher level of control.

Consider the following points before choosing a control level.

a) The outlet air temperature of a system will vary by an amount equal to the total temperature rise divided by the number of stages available. This may or may not be significant depending on the application. The effect of the temperature variation depends on the percentage of the total heating load supplied by the air handling system and the effectiveness of air diffusion in the area heated.

b) The critical level of comfort for the occupants must be considered.

c) If the HAV unit will use a significant percentage of the available building power supply, staging or sequencing should be specified to prevent voltage drops on unit cycling.

LEVEL #1: *Basic on/off control using remote or unit mounted single stage thermostat*
Fan operates continuously or on thermostat demand (field interchangeable.)
Heating circuit contactor(s) are energized when thermostat contacts close on temperature drop. When thermostat is satisfied the heating circuit is de-energized. High amperage loads will be sequenced on and off as a standard feature.

LEVEL #2: *Basic on/off control using 2, 3 or 4 stage remote or unit mounted thermostat(s)*
Fan operates continuously or on thermostat demand (field interchangeable.)
Each thermostat stage controls one heating stage. As the temperature sensed by thermostat drops, heating stages will be added in sequence. As temperature sensed by thermostat rises the heating stages will be de-energized, in reverse sequence. The system has a tendency to stabilize at a point where the connected heating load approaches the heating requirements.

LEVEL #3: *On/off control using one unit mounted thermostat for each stage sensing inlet air.*
Continuous fan operation (1 to 6 stages). Thermostats are preset to energize heating stages at specific declining inlet air temperatures.

LEVEL #4: *Proportioning step control with temperature controller sensing discharge air.*

An integrating control band concept to provide close, stable temperature control in discharge air temperature control systems – within the limits of total temperature rise and number of stages applied. Discharge temperature reset from room thermostat control available.

LEVEL #5: *Proportional step control with temperature controller sensing room temperature*
Heating stages are proportionally energized as the room temperature declines below the controller set point. Heating stages are added or removed by the step controller in order to maintain the desired room temperature.

LEVEL #6: *Solid state control with base load(s) with proportioning controller sensing outlet air temperature.**
See Level #8 for details of SCR operation. Base load(s) are added, prior to the SCR reaching its "fully-on" operation, by individual thermostats. The purpose of the base loads is to reduce the SCR capacity and cost and/or to reduce the size of the modulated heating load, while maintaining control precision.

LEVEL #7: *Solid state control with base load actuated by a single sensor.**
See level #8 for details of SCR operation. Electronic sequence controller adds or deletes the base loads as required.

LEVEL #8: *100% solid state control, with proportioning controller.**
Time proportioned control is achieved by the SCR adjusting the ratio of heater ON-time to OFF-time in response to a sensor input signal. Power to the load is modulated at a value between 0% ON-time and 100% ON-time depending upon the deviation from sensor setpoint temperatures. Duration of each ON/OFF cycle is approximately 8 seconds. Zero voltage firing of the solid state switching devices, on all cycles, minimizes radio frequency interference.

LEVEL #9: *Solid state control, with proportioning thermostat and low limit control**
Operates as described in either levels 7 or 8 with the addition of a low limit controller which insures that supply air temperature will not fall below a predetermined level.

*SCR controls used with outdoor HAV units must be mounted remotely in warm dry locations

OPTIONS

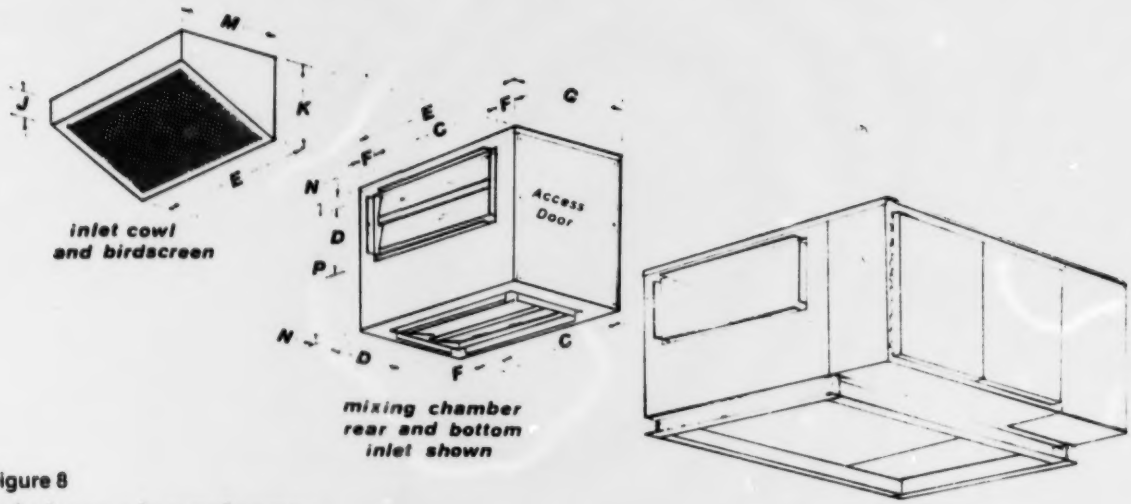


Figure 8

mixing chambers:

Figure 9

vertical units:

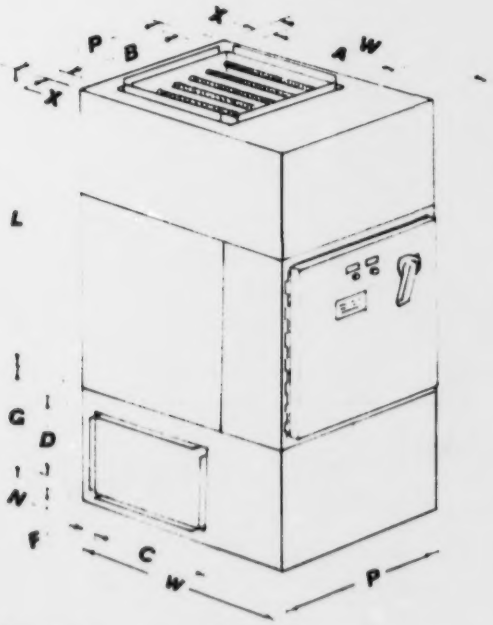
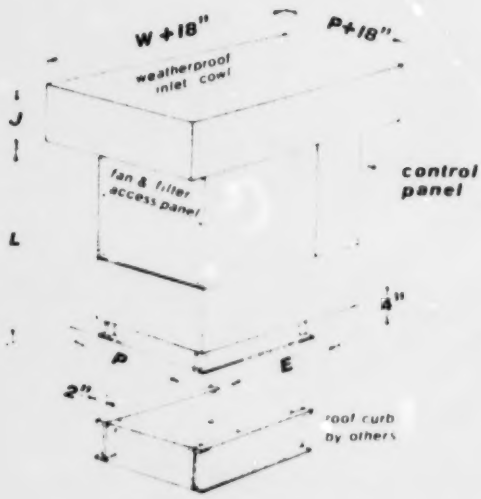


Figure 10 *vertical HAV unit upflow with mixing box shown also available in downflow*

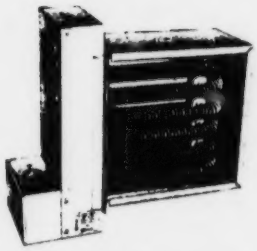


downflow rooftop make-up unit

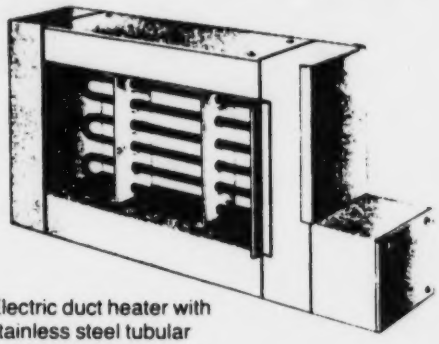
Figure 11

5-10

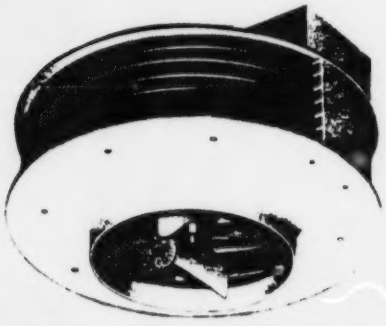
Related Chromalox Comfort Conditioning Products



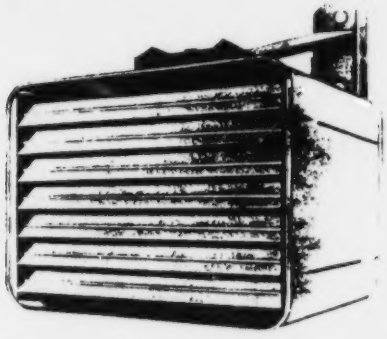
DHF/DHI – Electric duct heater with ceramic coated tubular heating elements and galvanized frame.



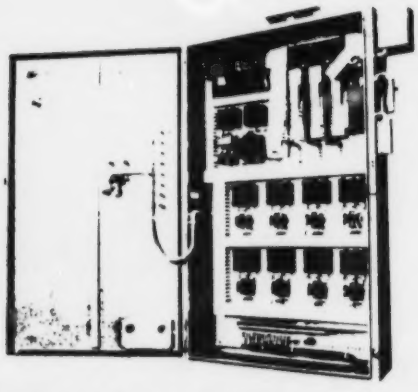
FDH – Electric duct heater with stainless steel tubular heating elements and galvanized frame.



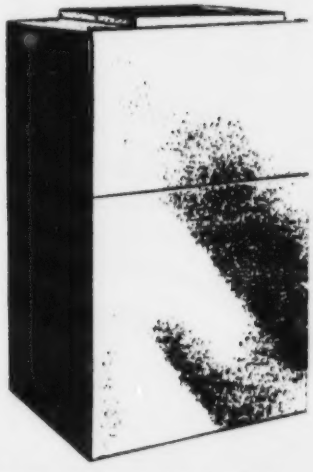
VUB – Forced air vertical unit heater.



BUH – Blower unit heater.



Control Panel – Custom engineered factory prewired control panel.



HAF – Residential forced air furnace.

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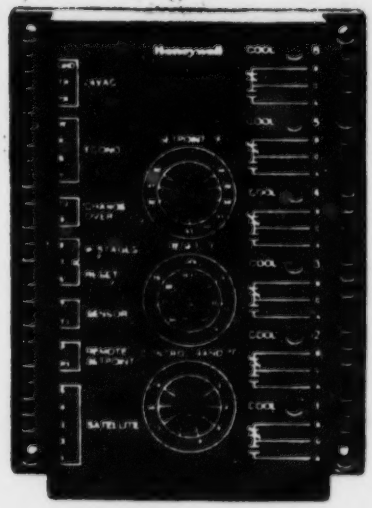
Honeywell

DISCHARGE AIR CONTROLLER

THE MICROPROCESSOR-BASED W7100 DISCHARGE AIR CONTROLLER MAINTAINS AN AVERAGE DISCHARGE AIR (DA) TEMPERATURE IN VARIABLE AIR VOLUME (VAV) COOLING SYSTEMS BY MODULATING AN ECONOMIZER AND SEQUENCING STAGES OF MECHANICAL COOLING. THE W7100 IS ALSO APPLICABLE TO ELECTRIC MAKEUP AIR AND OTHER SYSTEMS REQUIRING DISCHARGE AIR CONTROL OF MULTISTAGE HEATING OR COOLING.



- Available in cool only, heat only, heat/cool stage sequencing, and modulating heat/cool.
- Staging capacity of the W7100 may be extended using a W7101A Satellite Sequencer.
- Advanced microprocessor control algorithms minimize droop.
- Adjustable control band from 2 F to 16 F [-17 C to -9 C].
- Provision for systems without an economizer.
- Adjustable DA set point from 40 F to 90 F [4 C to 32 C] on cool only and heat/cool models; 40 F to 140 F [4 C to 60 C] on heat only and modulating heat/cool models.
- Adjustable reset of DA set point within range of 5 F to 20 F [3 C to 11 C] upward on cooling, 20 F to 80 F [11 C to 44 C] downward on heating. Reset signal can be from space sensor or outdoor air sensor.
- C7100 platinum resistance element provides highly accurate and stable DA temperature sensing.
- LED's on W7100A,B,C, and E panels show which stages of heating or cooling are on.

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N.J.
REV. 4-82•

Form No.
60-2507—2

W7100A-E

epc
Energy Products Center

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SPECIFICATIONS

MODELS: W7100 Discharge Air Controller—see Table 1.

TABLE 1—W7100 DISCHARGE AIR CONTROLLER MODELS

MODEL	ECONOMIZER	MODULATING HEAT OUTPUT	MODULATING COOLING OUTPUT	HEATING STAGES[b]	COOLING STAGES[b]	TEMP. RANGE F	TEMP. RANGE C
W7100A	Yes	No	No	None	6	40 to 90	4 to 32
W7100B	Yes	No	No	6	None	40 to 140	4 to 60
W7100C	Yes	No	No	2	4	40 to 90	4 to 32
W7100D	Yes	Yes[a]	Yes[a]	None	None	40 to 140	4 to 60
W7100E	Yes	Yes	No	1	4	40 to 90	4 to 32

[a]W7100D has single selectable modulating output—either heat or cool.

[b]Number of W7100 stages can be increased by 6 stages—4 cool and 2 heat, or 2 cool and 4 heat—using W7101 Satellite.

ELECTRICAL RATINGS:

Input Voltage and Frequency (terminals TR-TR)—20 to 30 Vac at 60 Hz, (20 to 26.4 Vac at 50 Hz).

Power Consumption—12 VA at 24 Vac and 50 to 60 Hz.

CONTACT	VOLTAGE (V)	INRUSH (VA)	RUNNING (VA)
N.O.	24	240	60
N.C.	24	75	30
N.O.	120/240	750	75
N.C.	120/240	240	40

SWITCHING (on/off stages): Spdt relays

WIRING TERMINALS: 1/4 in. quick-connect type.

INPUT SIGNAL: DA sensor—positive temperature coefficient of 4.8 ohms/degree F [8.6 ohms/degree C] resistance of 3484 ohms at 77 F [25 C].

CONTROLLED STAGES: Resistor value (across terminals 7 and 8) to determine number of on-off stages controlled by W7100. Varies from 100 ohms for 1 stage to 1000 ohms for 10 stages with W7101 (see Table 2).

AMBIENT TEMPERATURE RANGE: Minus 40 F to plus 150 F [minus 40 C to plus 66 C].

MOUNTING: Four mounting holes in base accept No. 8 screws (screws not provided).

DIMENSIONS: See Fig. 1.

UNDERWRITERS LABORATORIES INC. COMPONENT RECOGNIZED: Guide No. SDFY2, File No. SA481.

CANADIAN STANDARDS ASSOCIATION CERTIFIED: Guide No. 400-E-0, File No. 46034.

ADDITIONAL SYSTEM COMPONENTS:

Discharge Air Averaging Sensor (required)—C7100A1015 senses average DA Temperature, provides input to W7100 sensor terminals T and T1.

Transformer (required)—Provide 24 Vac power for all components of the W7100 control system. (Size transformer to match system load.)

ORDERING INFORMATION

WHEN PURCHASING REPLACEMENT AND MODERNIZATION PRODUCTS, USE COMPLETE ORDERING NUMBER, AND SPECIFY—

1. Order number.
2. Accessories, if desired.
3. Order additional system components and system accessories separately.

IF YOU HAVE ADDITIONAL QUESTIONS, NEED FURTHER INFORMATION OR WOULD LIKE TO COMMENT ON OUR PRODUCTS OR SERVICES, PLEASE WRITE OR PHONE:

1. YOUR LOCAL HONEYWELL RESIDENTIAL GROUP SALES OFFICE (CHECK WHITE PAGES OF PHONE DIRECTORY).
2. RESIDENTIAL GROUP CUSTOMER SERVICE
   HONEYWELL INC., 1885 DOUGLAS DRIVE NORTH
   MINNEAPOLIS, MINNESOTA 55422 (612)542-7500

   (IN CANADA—HONEYWELL CONTROLS LIMITED, 740 ELLESMERE ROAD, SCARBOROUGH, ONTARIO M1P 2V9) INTERNATIONAL SALES AND SERVICE OFFICES IN ALL PRINCIPAL CITIES OF THE WORLD

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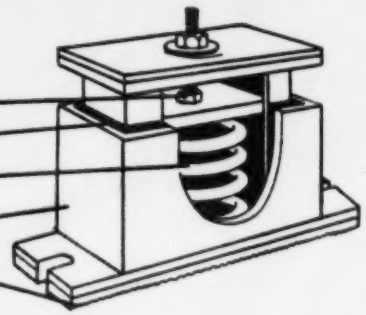
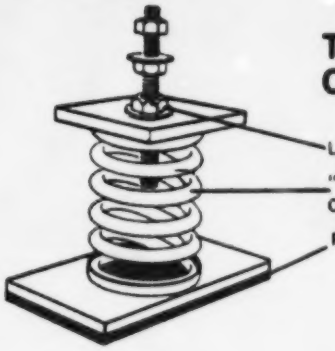
TYPES OF ISOLATION

TYPE CM

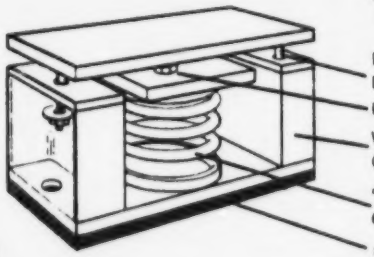


TYPE FS OPEN TYPE



TYPE SH

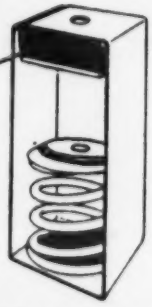
TYPE CSR



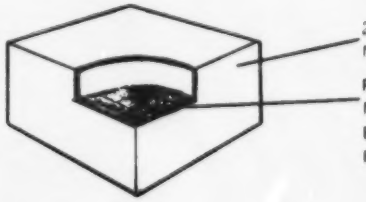
TYPE SHR

1" RUBBER ELEMENT

ALL OTHER DETAILS AS FOR TYPE SH

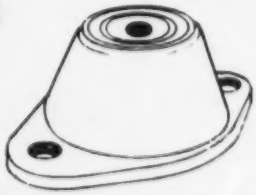


TYPE KIP

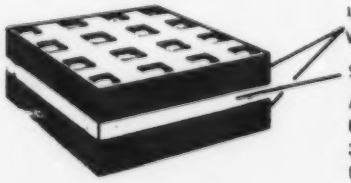


TYPE RM & RDM

NEOPRENE-IN-SHEAR WITH THREADED INSERT AND HOLD DOWN BOLT HOLES

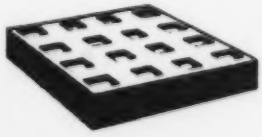


TYPES RSR NSN



TYPE R

¼" OR ½" ELASTOMER WAFFLE PAD AVAILABLE IN NATURAL RUBBER(R) 30 & 50 DUROMETER NEOPRENE (N) 50 DUROMETER



FOR APPLICATION SEE VIBRATION ISOLATION SELECTION GUIDE VIB.020.1

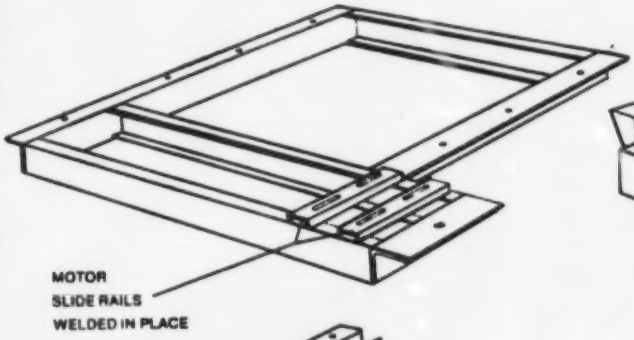
Vibro-Acoustics®

TYPICAL VIBRATION ISOLATORS

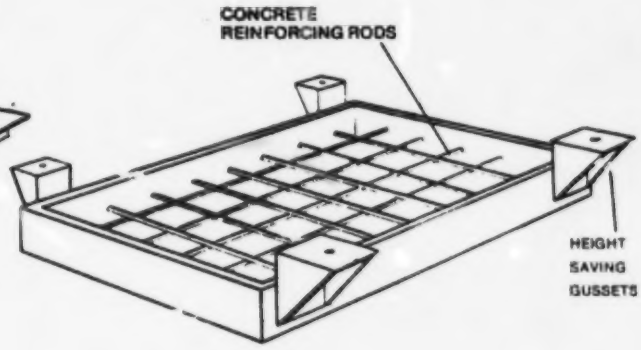
VIB - 030.1

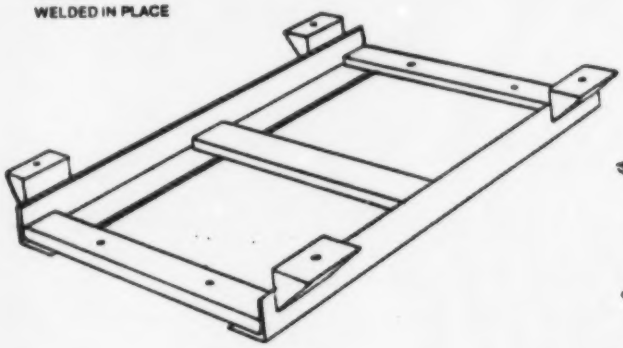
TYPES OF BASES

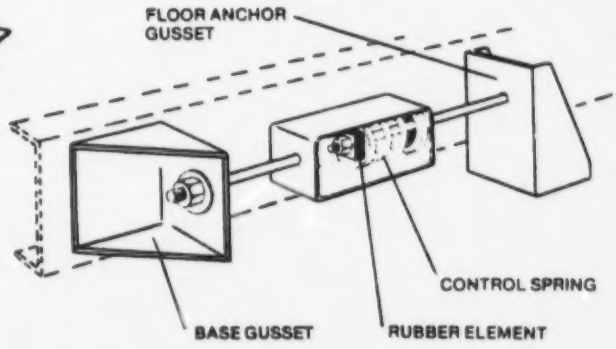
TYPE S INTEGRAL STEEL BASE
ALL WELDED CONSTRUCTION



TYPE C CONCRETE INERTIA BASE
ALL WELDED CONSTRUCTION







TYPE SS SLUNG STEEL BASE
ALL WELDED CONSTRUCTION

TYPE HCS TYPICAL HORIZONTAL
CONTROL SPRING

FOR APPLICATION SEE VIBRATION ISOLATION SELECTION GUIDE VIB.020.1

Vibro-Acoustics®

TYPICAL
VIBRATION ISOLATORS

VIB - 030.1